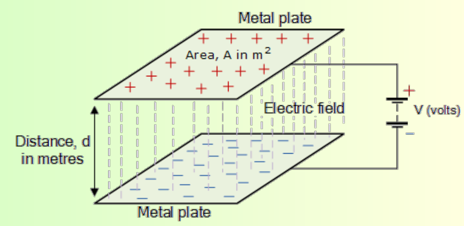
Capacitors	**Capacitors 2 - connecting capacitors**

Learning objectives	**MUST (C)**	Explain how the structure of a capacitor affects its properties
	SHOULD (B)	Understand the derivation of the rule for finding total capacitances for capacitors in series/parallel
	COULD (A/A*)	Calculate the capacitances of different capacitor combinations

STARTER: We know that the amount of charge that a capacitor can store is expressed by its **capacitance** (C). What physical features of a capacitor do you think affect its capacitance?

EXTENSION: What factors do you think an equation to calculate capacitance would contain, and how would they relate (proportional, inverse...) to the capacitance?



$$C = \frac{\varepsilon A}{d}$$

Where,

$C =$ Capacitance in Farads

$\varepsilon =$ Permittivity of dielectric (absolute, not relative)

$A =$ Area of plate overlap in square meters

$d =$ Distance between plates in meters

Why is d inversely proportional to C?

Because the further apart the plates, the lower the electrostatic field between them.

Capacitors 1 homework: answers

1. C
2. C
3. D
4. A
5. D
6. B
7. D
8. B

Capacitors	**Capacitors 2 - connecting capacitors**
MUST (C)	Explain how the structure of a capacitor affects its properties

The equation for capacitance for a parallel plate capacitor with a vacuum between the plates is:

$$C = \frac{\varepsilon_0 A}{d}$$

ε_0 is permittivity of free space, 8.854 x 10^{-12} F m^{-1}

A is area of overlap, *d* is separation: convert units to m

When an insulator (or dielectric) other than a vacuum is used, the equation used is:

$$C = \frac{\varepsilon A}{d}$$ where $\varepsilon = \varepsilon_r \varepsilon_0$ and ε_r is **relative** permittivity.

Material	ε_r
vacuum	1 (by definition)
air	1.0006
perspex	3.3
paper	4.0
mica	7.0
barium titanate	1200

ε is the permittivity for the insulator.

Two square completely overlapping plates with side length 1 cm, 2 mm apart, with a perspex dielectric. What is the capacitance? ε_0 is 8.854 x 10^{-12} F m^{-1}

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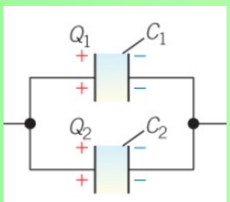
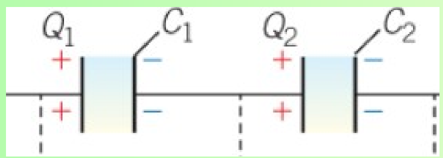
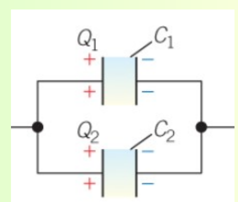
Capacitance	**Capacitors 2 - connecting capacitors**
SHOULD (B)	Understand the derivation of the rule for finding total capacitances for capacitors in parallel/series

Connecting capacitors in parallel and in series; will the overall capacitance increase or decrease?





Capacitors in parallel: the same V is across both capacitors.



Total charge $Q = Q_1 + Q_2$ (conservation of charge)

Recalling that $Q = CV$

If C is total capacitance, $CV = C_1V + C_2V$

V is the same in each case, so cancels out: $C = C_1 + C_2$

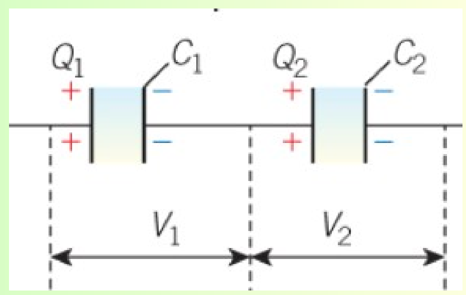
Total capacitance of capacitors in parallel = sum of the capacitances

Capacitors	**Capacitors 2 - connecting capacitors**
SHOULD (7)	Understand the derivation of the rule for finding total capacitances for capacitors in parallel/series

Capacitors in series

Potential difference split between the two capacitors.

Q is the same for all capacitors



Total p.d. $V = V_1 + V_2$

$V = Q/C$

$Q/C = Q/C_1 + Q/C_2$

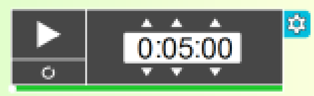
Cancel out by Q throughout to give: $$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2}$$

Capacitors	**Capacitors 2 - connecting capacitors**
COULD (A/A*)	Calculate the capacitances of different capacitor combinations

Complete:

Summary questions 1-3 in section 21.2.

Summary questions 4-6 in section 21.2.



Key points:

Series: Q is constant, and $1/C = 1/C_1 + 1/C_2$....

Parallel: V is constant, and $C = C_1 + C_2$

21.2

1 Parallel: $C = C_1 + C_2 = 100 + 100 = 200\,\text{pF}$ [1]

Series: $C = (C_1^{-1} + C_2^{-1})^{-1} = (100^{-1} + 100^{-1})^{-1}$ [1]

$C = 50\,\text{pF}$ [1]

The total capacitance for the parallel circuit is **twice** the capacitance of a single capacitor [1] and the total capacitance for the series circuit is **half** the capacitance of a single capacitor. [1]

2 $C = (C_1^{-1} + C_2^{-1})^{-1} = (120^{-1} + 120^{-1})^{-1}$ [1]

$C = 60\,\text{nF}$ [1]

$Q = VC = 60 \times 10^{-9} \times 1.5$ [1]

$Q = 9.0 \times 10^{-8}\,\text{C}$ [1]

3 Total capacitance of N identical 1000 μF capacitors in parallel = $N \times 1000\,\mu\text{F}$ [1]

Therefore, $N \times 1000 \times 10^{-6} = 4000$ [1]

$N = 4 \times 10^6$ (4 million) in parallel [1]

4 $C_1 = (100^{-1} + 500^{-1})^{-1} = 83.3\,\mu\text{F}$ [2]

$C_2 = (50^{-1} + 200^{-1})^{-1} = 40\,\mu\text{F}$ [2]

Total capacitance = $C_1 + C_2 = 83.3 + 40 \approx 123\,\mu\text{F}$ [1]

5 The charge stored by each is the same and the p.d. across the combination is 6.0 V. [1]

$V = \frac{Q}{C} \propto \frac{1}{C}$, hence the p.d. across the capacitor with capacitor $2C$ will be half the p.d. across the capacitor with capacitance C. [1]

Therefore, p.d. across $C = 4.0\,\text{V}$ [1] and the p.d. across $2C = 2.0\,\text{V}$. [1]

6 $\frac{1}{17} = \frac{1}{C} + \frac{1}{20}$ [1]

$\frac{1}{C} = \frac{1}{17} - \frac{1}{20}$ [1]

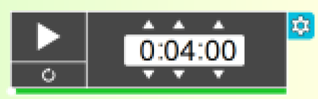
$C = 113\,\text{nF} \approx 110\,\text{nF}$ [1]

Capacitors	**Capacitors 2 - connecting capacitors**

Learning objectives	**MUST (C)**	Understand the derivation of the rule for finding total capacitances for capacitors in parallel
	SHOULD (B)	Understand the derivation of the rule for finding total capacitances for capacitors in series
	COULD (A/A*)	Calculate the capacitances of different capacitor combinations

PLENARY: Three capacitors are in series: 10μF, 20μF and 40μF. Which (if any) has the highest potential difference across it? Why?

EXTENSION: What do we know about the total capacitance? Answer without any calculation.



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